Review of the UCERF3 Project Plan v30

by the Scientific Review Panel (SRP)

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Introduction

This is an ambitious plan that attempts to make substantial progress on a number of fronts. The SRP is impressed with the scope of the plan and the thoughtful itemization of tasks. A lot of work and thought has gone into the development of this plan. There is a lot of exciting research described, and it is exciting to see this field of work advancing so quickly. Some of the goals relate to issues (listed on p. 3) that were not resolved in UCERF2 ("Empirical Model", segmentation, etc.), while others (rapid updating to account for earthquake sequences) bring new components to the model.

Such an ambitious undertaking will require careful planning and management to achieve its many goals. There may turn out to be too much in the plan to accomplish in the limited time. If so, this should not be viewed as a failure, because these are serious and complicated issues, and the task before the Working Group is not only to advance research, but to bring new ideas to a sufficient state of maturity that they may be comfortably used in setting public policy. To do this at all is commendable; to do it under time pressure is impressive.

Given the limits of time and staff, most attention needs to go to critical tasks, and less-critical tasks need to be excised or at least assigned a lower priority. We expect to see some narrowing of scope over the coming six months, as the Working Group assesses the progress of various tasks and begins writing the methodology assessment due in December.

Given the limited time permitted for review, members of the SRP identified a number of technical points that have not been included in this summary review. We will work to bring those points to the attention of the Excom, perhaps through additional short committee reports or other means.

Overarching comments

There are many promising and ambitious research paths identified and planned. While many will bear fruit, it can be expected that some will not, either because the path doesn't lead where expected, or because there is not enough time and manpower, or because concerns are raised in review. It would be useful to see this recognized as a possibility, with a statement about how the Excom will deal with this issue. We assume that the UCERF2 model is the default state and fall-back position, with alterations made to it only where new model components are determined to be sufficiently developed, reviewed and "ready for prime time." Put in terms of a logic tree, the UCERF3 model will preserve the structure of UCERF2, with new branch structures that will gain non-zero weight once they are developed and vetted. If we are wrong in this assumption, that should be made clear.

Tie to National Seismic Hazard Maps. There is agreement among the SRP members that the UCERF3 model should yield a long-time-frame earthquake forecast that matches that underlying the National Seismic Hazard Maps. We acknowledge that this places constraints on the model; however, we simply cannot have 2 different models or maps for use in public policy. Therefore, it is important that the WGCEP and the National Seismic Hazard Map project work closely together so that the National map can make maximum use of the UCERF results. (The question arose in discussion whether the UCERF model really would yield a "time-independent" forecast, especially given references to time-varying rates at a variety of scales. It might be useful to define terms in this case.)

Short-term probabilities. An important new direction in UCERF3, compared to its predecessors, is the modeling and prediction of short-term behavior. The SRP would have liked to see a framing discussion of this topic, beginning with a discussion of the user needs (probabilities of what? On what time frame and in what level of detail?). It is not clear from the plan whether the long-term and short-term probabilities will be tightly coupled or largely separate (as they are in STEP, e.g.). It is also not clear what the Excom believes falls within the term "operational earthquake forecasting" and whether the needs of CEA for a "living model" that dynamically adjusts probabilities (only?) following a significant earthquake is in the same "operational" class as a STEP-like model that updates probabilities continuously. The plan would be improved with an introductory discussion of the main model outputs, in various time frames of interest.

Role and definition of expert opinion. In some places the plan reports the need of 'expert opinion', and in others the goal is to avoid the need for opinion by constructing objective models. It would be useful to clarify the role of expert opinion in model building and operation of the model. For instance, it is not clear how it is used in practice to get a probability and/or to merge different models. Is there a formal elicitation? Is a logic tree used? If so, how are the weights estimated? It seems that expert opinion is the 'glue' among different scientific components; the document describes the components, not the glue. As desirable as it may be to make a model that is free of judgment calls, they will be unavoidable. Where there is legitimate bredth of opinion within the scientific community about how certain problems should be approached, judicious use of expert elicitation can properly capture this important source of epistemic uncertainty.

Model modules. The rationale behind the subdivision into four modules is not completely clear, especially to new members of the SRP. The first two modules are well characterized from a scientific point of view and in a logic order (i.e., the fault database has to be before the determination of the slip rates), while the third and fourth modules seem characterized by their

kind of output rather than from the scientific components. For instance, it seems that the main rationale of the third module is to create a link with the national hazard map, but it is not clear how this may happen. Moreover, some tasks (like the studies of the "empirical model") seem equally important for both, not just for one of them. Many of the tasks may be moved from one module to the other, simply because a reliable model for the rate should be good also for probability estimation (at least in the same forecasting time window).

Role of simulators. SRP members are generally satisfied with the plan to explore the use of earthquake simulators to explore model behavior. The physics-based approach, while obviously not able to simulate physical reality completely, provides a powerful set of capabilities for exploring the parameter space of the space-time patterns of seismicity along large scale fault systems. Their use in a heuristic sense is justified and some abstraction of common or iconic geometries within the California fault systems might be helpful for simplification. The Excom appears to share the view of the SRP that it would be difficult to justify using simulators directly in the model calculations.

*Participation***.** In reviewing the many tasks and their participants, some concern was expressed about the level of commitment being made by the people listed as "Participants" in each task. Several SRP members were surprised to see their names listed, for example, which drew into question the actual commitments by others. It would probably be better at this point in time just to list the name(s) of the task leader(s) until the participant specifics can be worked out. Also, there was agreement in the group that SRP members should not actively participate in tasks, if possible. (There will be exceptions, such as Art Frankel's participation in the development of the model for Cascadia, as he is doing this as part of the National Map effort.)

Document organization and plan presentation

Document organization. The document is quite rich in content. However, its organization is somewhat cumbersome and uneven. Tasks are described in three places: In the “Main Model Components” subsections, in the Tasks table, and in the appendices. It would be worthwhile to bring the “F1” organizational scheme into the first of these, evening out the amount of detail. The task descriptions in the summary table were written before the extended task descriptions; many ask questions and read like brainstorming sessions. In a formal document these need to be brief and consistent (some readers will only look at the summary table). The executive committee needs to systematically review/revise these summaries to insure they reflect what's in each task description. In the body of the plan, each section describing a model component should start with an overview of the intent of the component, what will come from it, and the key issues. It's important that the plan clearly state why each task is being undertaken and how it will fit into the UCERF3 analysis. Finally, it will be worth having an independent set of eyes read through the final draft with the goal of smoothing out the language, expunging redundancy, and correcting typos.

Modeling approach. The organization of the document, and the scope of its contents, presume that the reader has a good familiarity with UCERF2 and the overall WGCEP/UCERF approach to calculating earthquake likelihoods, a summary of which exists only as Figure 1. Although it would be cumbersome and probably unnecessary to completely describe the modeling approach and design, it might be worth adding some framing language near the front, to explain some of

the key points. For example, it is not clear whether the model has a logic tree as its foundation, and if so, the procedures for determining its branches and their values and weights.

Missing pieces. The task appendix is incomplete, missing F3, F4, R6, and perhaps others. Given that R6 is proposed as the likely cure for too many M6.5-7 events it would have been appropriate for the SRP to have seen it. The report can't be sent with missing task descriptions.

Disconnects. There is a disconnect between the extended task descriptions and the task summary given in the table of tasks. For example, for F1 the summary table states "We also need to consider the need for sub-sectioning faults at points on the trace that are in close proximity to the end of another fault (e.g., a "Y" shaped fault should be composed of at least three sections)." There is no reference to this in the extended task description. For F2 the summary table description lists two questions, not a summary of the task. The second question reads " Use double-difference relocated seismicity data?" There is a reference to this in part of one sentence in the extended summary.

Fault models

There are four proposed tasks: F1) Update Faults; F2) Reevaluate Fault Endpoints; F3) Database Issues; and F4) Compile Slip in Last Event Data.

The task descriptions for F1 and F2 adequately lay out the issues and approaches to be used to update the UCERF 3 fault model database and develop a database of fault endpoint characteristics for use in evaluating the linking of individual faults into longer ruptures and the probabilities of fault-to fault jumps. It would be useful, however, to clarify the type of revisions, if any, UCERF 3 is likely to make to the Statewide Community Fault Model as part of task F1.

There is no extended task description for F3. The summary table description does not provide a clear statement of where this task is heading. In fact, the SRP questions whether there is really a task here. Can decisions about database issues simply be made by the Executive Committee (in consultation with Haller and others)?

There is no extended description of F4. The topic of the task, slip in the most recent event (MRE), would actually fit better under Earthquake Rate Models along with tasks such as R12 (Distribution of Repeated Slip at a Site on a Fault). If this task is to be included in the project it requires a task description. It is difficult for the SRP to evaluate what might be done without this. We note that there are very few published data on MRE slip for faults in the UCERF fault model, so developing new information, if possible, is a worthwhile effort.

Lidar. The summary suggests the possibility of using Lidar high resolution topography for constraining MRE dates. If this is the case we will refer the Executive Committee to extended comments of Arrowsmith and Schwartz on this issue.

Alphabet of faults. Given that this is a lengthy planning process, and a nice opportunity to try to break out of a set way of thinking, it would be good to get rid of the A-B fault dichotomy and treat the faults as a range of objects with a more smoothly varying degree of understanding. Ideally, the model should yield narrower uncertainty bounds for better-understood faults. For example, the magnitude-frequency distribution for those currently called B faults should include that found for A-faults plus additional uncertainty.

A related question is whether all faults can be assumed to be statistically similar (obeying statistically similar physics), or should they be classified into classes representing different conditions (e.g., geometrical complexity, ambient heat flow, fluid activity, existence of pronounced bimaterial interfaces) that may affect the earthquake productivity, rupture behavior and expected shaking. This of course introduces additional complexity and details that can probably not be resolved in the course of UCERF3. But perhaps it would be useful to discuss (maybe as a prelude to UCERF4) the general question of whether or not all earthquakes and faults should be assumed to be statistically similar.

Cascadia. In UCERF2, Cascadia was handled almost entirely separately from the rest of the state, which could be rationalized on the basis of tectonics but which was found to be awkward by the SRP and others. It appears that a similar tact approach will be followed here. It would be useful to address this issue head-on, with at least a paragraph that explains the Working Group's intentions.

Deformation models

D1: The SRP has doubts that that questions 3 through 6 can be answered using geodetic data, primarily because of the well-known instability of the inverse problem of inverting for fault slip given only surface motion. This is exacerbated by the uneven distribution of monitoring stations. A more fruitful approach might be to ask, what range of slip models are consistent with the observed motions? To make the space of acceptable slip models tractable it may be necessary to include a fair amount of geological constraints. Likewise, Dave Sandwell's comparisons have shown the very great difficulty in getting precise strain-rate estimates from scattered velocity data; again, using the data to limit the range of models seems more promising.

D3: Other than the name (aren't these really dislocation tools?) this seems like a good if minor task; the comparison with the vertical seems worth doing but there may be enough other sources of vertical motion that one should not use this as a model test.

One general point is that the deformation comparison needs to take into account the possible long-term aftereffects of previous large earthquakes. Some investigators have argued that part of the observed current deformation reflects postseismic motions still present from the 1857, 1872, and 1906 earthquakes. This is a potentially major source of uncertainty that needs to be addressed at some level.

Earthquake rate models

Characterize the bulge. A great deal of emphasis is being made into developing model components that may help to reduce the "bulge"; however, we hope that the Working Group has done the work (or is planning to do the work) necessary to fully characterize the bulge and demonstrate it to be a (general) failing of the UCERF2 model and one that needs to be corrected across the entire model. For example, Figure 20 in the UCERF2 report suggests that the bulge is present only in the northern California portion of the model and is largely the result of an anomalously low rate of observed seismicity in a limited magnitude range of 6.5 to 7.0. As part of task R8 it would be worthwhile to investigate that bin, as well as the influence of earthquakes

near the boundary of the region (e.g., near Reno), and alternative methods for calculating earthquake rate from catalog data.

Another issue that doesn't get full attention in the plan is how to produce a physically-plausible seam between the gridded seismicity model and the fault model. This seam is also partly responsible for the bulge problem. How the transition is made between the stochastic and deterministic portions of the model is a tricky problem that deserves more attention than is described in the UCERF3 plan.

R8. This looks to be a useful approach. A key issue here is that it's clear that Toppozada's initial work for pre-1900 events needs to be revisited, and that the intensity values will generally be lowered. So the heights of all of those "tombstones" (i.e., the numbers of M 5.5 or larger) will be knocked down. The question is, how much would they have to be reduced to make the rate discrepancy disappear? Probably the rate discrepancy will be reduced but not disappear – but it would be useful to see the results of sensitivity tests; depending on the results, one could then reexamine a few test events. Please note that this step would need to be done with care and with the full engagement of those experienced in the interpretation of macroseismic data.

R10. The reviewers expressed many concerns about the estimation of M_{max} and its spatial variability. Despite the scientific rationale being clear and well taken, there are many doubts on how to estimate this important parameter from a limited set of data and information. For example, it is well-known that the estimation of an upper boundary of a (truncated) power-law distribution is very difficult from a statistical point of view; bias and large variance are quite common in these cases. Also the physical concept of a rigid upper limit is rather controversial.

R13. This task has been very appreciated but also controversial. There is a general consensus that simulators may represent the future, but much less optimism about how to use them in UCERF3. One specific problem is that simulators are quite complicated and it might be easy to reproduce the past just overfitting the data. This would lead to an exceptional success for the past but a completely unknown capability to describe the future evolution. (This is also the main reason that stands behind the choice to make prospective experiments in CSEP.)

Earthquake probability models

Operational? In this module it seems that the term 'operational' is used only for short-term forecasts. In general, 'operational' may be used also for long-term forecasts, because 'operational' means something that is authoritative - like UCERF is - and it may be used for taking risk mitigation actions. This may be done for different time windows, not necessarily for short-term. For example, defining building code is 'operational'. Of course you may have your own definition, but the meaning of 'operational' should be explained more clearly.

Clarify the various time scales. This module contains tasks dealing with completely different forecasting time windows (i.e., P1-P2 and P5-P6). Other tasks, like P8, discuss the Double Branching Model that has been set for long-term forecast together with ETAS models for short-term forecasting. Specifically, this task deals with time dependencies very different one from each other; one long-term dependency that may have some connection with the "empirical model", and one short-term dependency (due to technical problems as well as physical processes

like fluid intrusion, etc...). In summary, it would be good to clarify better the mission of this task and probably to keep more separated long- and short-term forecasting models.

Renewal models. A gap in the report is the lack of an appendix chapter on task P4, development of self-consistent renewal models. This is notable because these models directly influence the time-dependent earthquake probabilities and have been the subject of much discussion and controversy. Although the report refers to an appendix to the UCERF2 report, tt would be worth including a synopsis of the intended approach and the research needed to develop it.

Empirical model. Again, it appears strange to some that "Empirical model" is important only for this module. If not, it would be nice to see how this task interacts with the previous module (earthquake rate models), and also with the task of other (long-term) time-dependency (task P8).

Time-predictable model. The implication in the summary table is that the MRE slip will be used for time-predictable probability estimates. WGCEP 03 used a time-predictable model for only the San Andreas because there was available slip data from 1906. UCERF 2 did not use the time-predictable model. Where will the time predictable model be applied? Will it be used only for the San Andreas, or to a broader suite of faults? Some discussion of this should appear somewhere in the project plan. Again, the SRP members favor a model in which the same renewal model (or suite of models) may be applied to every fault, constructed such that faults with less information (e.g., no estimate of MRE slip) yield greater uncertainty.

ETAS. Some SRP members were troubled by the mention of "a simple ETAS model where the triggered events will be sampled from the long-term rate model (so that magnitude 8 events can only be triggered where such events exist in the long-term model)." It was not clear why triggered events would be sampled, nor why the model would require that magnitude 8 events only be triggered in the future where previous large events exist. The idea of including "sequence specific parameters" was also confusing, since that would seem to be adding a lot of estimated parameters, and would possibly remove the objectivity of ETAS and similar models and make them purely retrospective, since presumably one doesn't know that a sequence has occurred until afterwards.

Implementation

The several “implementation issues” listed in the Tasks table are not elaborated upon elsewhere.

A general comment is that there needs to be a more comprehensive effort to develop a consensus on the procedures to be used in UCERF3 from a wider group of scientists, and there needs to be a stronger effort to foster buy-in from the many users and stakeholders (an even larger number than before, thanks to the addition of short-term components). Many of the aspects of the plan are controversial, e.g., the use of a large-scale inversion to quantify the rates of thousands of rupture possibilities from limited data, the non-use of expert geologic opinion to inform the rupture characterization, the use of simulators to constrain time-dependent models, the inclusion of megaquakes from multiple-fault ruptures with some poorly constrained jumping probability, the use of short-term forecasting in the context of a fault model, etc. A broader group of scientists, PSHA practitioners, loss modelers, and engineers needs to weigh in on these procedures. Developing a wider consensus should be an explicit part of the UCERF3 plan.

The workshop scheduled for February, 2012 occurs too late to meaningfully influence the form of the model, yet too early for model results to be shared and discussed with practitioners. A better plan might involve two workshops, the first one much earlier, and the second after the initial model is developed. This workshop, convened in coordination with the National Seismic Hazard Mapping project, would show the users the effects of the changes from UCERF2 on both earthquake probabilities and hazard.

As mentioned earlier, the SRP strongly concurs with the need to maintain an ongoing dialog with the National Seismic Hazard Mapping project, so that UCERF3 model outputs can flow (with a minimum of heartache) into the NSHMP's Fortran codes.

From task I4 and language elsewhere in the document, a goal appears to be that UCERF3 will run in real time, providing a continuously updated state-wide forecast. It is not clear to the SRP whether potential users of that information have been identified and engaged, nor whether the CEA is among that set of users.

Concluding comments

This is an excellent project, and is being well managed and executed by the Excom and many dedicated colleagues. The SRP appreciates having had the opportunity to review and comment on the project plan at this early stage, and looks forward to our continued interaction.

We have learned through this initial, informal review that the allotted time was insufficient. There was enough time for the busy SRP members to read the document and return thoughtful comments, but not enough time for the committee to digest and discuss the many points raised, nor to prepare, circulate and edit this summary review. Before more time passes, there should be dialog about the calendar between the SRP, Excom and MOC, with the goal of adjusting delivery dates if needed, such that there is enough time in the schedule for reports to be composed, reviewed and finalized.